

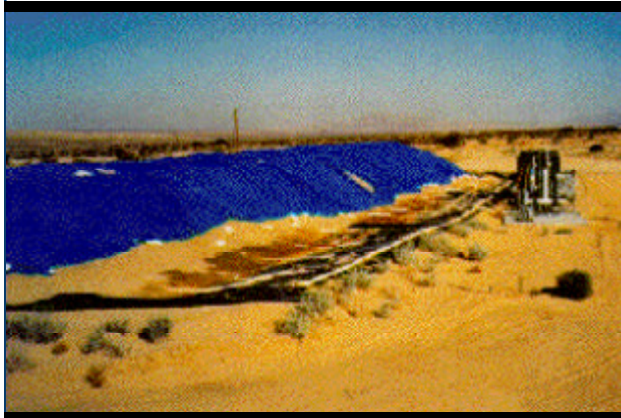


N F E S C

"Specialized facilities engineering and technology"

Biopiles

*A viable and cost effective method to remediate
hydrocarbon contaminated soil*



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What are Biopiles?

Under optimal soil conditions (non-compacted, sandy loam is ideal), indigenous microorganisms use hydrocarbons as a food source and convert them to carbon dioxide and water. **Biopiles** are facilities that use the bioremediation process to economically cleanup hydrocarbon-contaminated soils containing gasoline, diesel, and jet fuels. These systems consist of an aeration system to provide oxygen to the microbes, an irrigation/nutrient injection system to provide nutrients and moisture after pile construction, and a leachate collection system for controlling excess moisture in the pile. A liner, berm, and cover protect the soil piles from storm events and prevent the spread of contaminants. Remediation costs range from \$25 to \$70 per ton depending on the amount and type of soil, type and level of contamination, climatic conditions, site restrictions, and regulatory requirements. Remediation times vary depending on hydrocarbon concentrations, soil, nutrients, temperature, and microbial conditions.

Essential Bioremediation Components

Oxygen - For aerobic degradation of fuel contaminants, an oxygen level must be maintained in the soil pile. Oxygen is supplied by injecting air via a piping network in the soil pile. The system is closely monitored to maintain the soil oxygen content above 15%.

Water - Water is essential for microbial activity. While low moisture content will inhibit microbial growth and mobility, excessive moisture will clog soil pores, thereby restricting necessary airflow. Soil moisture is maintained in the pile at 70 to 95% of the soil field capacity.

Nutrients - The nutrients required for microbial proliferation are nitrogen, phosphorous, potassium, sulfur, magnesium, calcium, manganese, iron, zinc, and copper. Nitrogen and phosphorous are likely to be deficient in hydrocarbon-impacted soil. These nutrients are applied in solid or liquid form during soil pile construction and, if necessary, can be introduced through a drip irrigation system.

pH - Most hydrocarbon bacteria grow best at a neutral to slightly alkaline pH, thus, pH levels are maintained near 7,

but definitely within the 5 to 9 range. Where concentrations of aromatic compounds are present and where soils have low alkalinity, liming may be necessary.

Temperature - Temperature also affects biodegradation rate. Microbial activity slows when the temperature decreases, and very high temperatures can essentially sterilize soil, creating an adverse environment for certain microbial activity. When microbes digest hydrocarbons, heat is generated within the soil piles, often raising the soil pile temperature 10 to 30°F. Optimum biopile temperatures range from 50 to 100°F for a permanent concrete facility.

Microbial Population - The indigenous microbial population is sufficient for bioremediation, making it unnecessary to add microbes to the system. However, there are several commercially available bioaugmentation, nutrient, and surfactant products that may work with the indigenous microbes to augment remedial efforts.

Soil Characterization and Treatability Studies

Soil characterization prior to remediation is required to maximize bioremediation efficiency. This characterization provides baseline values for total petroleum hydrocarbons (TPH), the indigenous population of microbes (including hydrocarbon degraders), nutrient levels, pH, porosity, and moisture content. Further laboratory analyses are performed to determine optimal conditions necessary for expedite biodegradation. At designated intervals during bioremediation, parameters identified in the laboratory analysis can be monitored in conjunction with hydrocarbon levels. This facilitates tracking the contaminant degradation and guides system adjustments for optimal bioremediation.

System Construction

There are two different types of systems - temporary and permanent. In the temporary system, the biopile is built on top of a clean soil layer over a liner and base. In the permanent system, the clean soil layer is replaced by a concrete pad. Temporary facility construction costs are less than permanent concrete facilities. The major construction steps for a bioremediation facility are:

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- Choose site (level area not located in a flood plain)
 - Prepare site for pad construction
 - Construct pile base
 - Install liner
 - Install protection over liner to prevent puncture during construction
 - Construct clean soil layer and concrete pad
 - Install piping for vapor extraction/air injection unit
 - Install irrigation/nutrient injection system
 - Install leachate collection system
 - Load soil into facility
 - Begin remediation

System Monitoring

Data are collected immediately after startup and at designated intervals during the bioremediation process to monitor the system's performance. These data are used in conjunction with computer-based models to determine if airflow adjustments are necessary.

The probes are constructed using 0.020-inch slotted, 2-inch PVC piping and are placed vertically at varying depths within each pile. The probes are capped and connected to Tygon tubing that leads to the surface of the pile. The end of the tubing is fitted with a valve to allow for vacuum readings and to monitor oxygen uptake.

The probes are also used to monitor TPH, carbon dioxide, and oxygen concentrations throughout the pile. For carbon dioxide, the air stream is monitored with a meter calibrated to 2.5% carbon dioxide with a nondispersive infrared (NDIR) light of a specific wavelength. For oxygen, a portable oxygen meter using electrochemical sensors calibrated to atmospheric oxygen concentrations of 21% is used.

Microbial activity evaluation includes enumeration of heterotrophic and hydrocarbon degrading soil microbes in treated soils using standard plate-count and most probable number (MPN) laboratory techniques. Also, oxygen uptake rates are measured and compared to microbial activity -- a decrease in microbial oxygen uptake consumption indicates a system deficiency or approaching the end of the remediation process. Oxygen uptake rates are determined by temporarily turning off the aeration system and monitoring oxygen and carbon dioxide concentrations are monitored at 2-hour intervals.

Case Studies

Camp Pendleton, CA (Permanent Facility)

Permanent facilities are built when substantial quantities of contaminated soils exist or are anticipated from large tank pull programs requiring numerous batches to be treated over several years. The facility at Camp Pendleton can remediate approximately 7,200 tons of soil per cycle. A cycle can take 3 to 4 months, depending on the type of hydrocarbon and the concentration levels.

This permanent facility is constructed on two 200- by 100-foot, 8-inch thick concrete pads underlain with a 60-mm high density polyethylene liner (HDPE). Each concrete pad is sloped 1 degree and contains 12 troughs approximately 60 feet long, 1 foot wide, and 8 inches deep, spaced 15 feet apart equidistant from each side of the pad. Each trough contains part of the aeration system, 2-inch slotted PVC piping covered by 6 inches of gravel and a metal grate. The troughs also serve as drains for collecting soil leachate, which is stored in holding tanks and can be recycled if necessary. The trough piping is connected to a vapor extraction unit that draws air through the soil pile raising soil oxygen content to the necessary level for microbial stimulation.

A trapezoidal soil pile approximately 8 feet high is formed over the 12 troughs. Moisture and nutrients are added as the pile was built. An irrigation system is installed to allow for water and nutrient addition as well as pH control after pile construction. This system can use fresh or recycled water.

Water runoff and atmospheric emissions from the soil piles are minimized by an impermeable cover placed on top of the soil pile. As air is pulled through each pile, vapors are separated via an air/water separator. After air passes through the blower, carbon canisters filter the air before it is exhausted to the atmosphere.

National Test Location, Port Hueneme, CA (Temporary Facility)

Temporary facilities are used to treat smaller quantities of contaminated soil or when permanent concrete facilities are cost prohibitive. The National Test Location (NTL) facility can remediate approximately 400 tons of soil per cycle. Like the permanent facility, a complete cycle can take 3 to 4 months depending on the type of hydrocarbon,

its concentration, and type of soil. Although temporary facilities are built with an HDPE liner placed over a 6- to 12-inch sand base (replacing the concrete pad), the NTL facility had an existing asphalt base, therefore, a felt pad was placed directly over the asphalt and a 52- by 52-foot HDPE liner was placed on the felt pad. The liner was covered with 8 to 12 inches of soil to protect the liner during heavy soil moving operations. Three 4-inch slotted PVC pipes spaced 10 feet apart were placed on the 12-inch soil base and covered by a 6-inch radius of pea gravel.

The remainder of the pile construction was similar to the permanent facility. A trapezoidal soil pile approximately 8 feet high is formed over the temporary pad system. Moisture and nutrients are added as the pile is formed; piping is connected to a vapor extraction unit that draws air through the soil pile. As air is pulled through the pile, the vapors are separated via an air/water separator. A drip irrigation system is installed, and water runoff and atmospheric emissions from the soil piles were minimized by an impermeable cover.

For more information on this treatment process,
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